HT

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 428 505 B2

(12) # NEW EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the opposition decision:
14.03.2001 Bulletin 2001/11

(45) Mention of the grant of the patent:
20.12.1995 Bulletin 1995/51

(21) Application number: **91102481.8**

(22) Date of filing: **28.05.1986**

(51) Int Cl.[7]: **G05B 19/10**

(54) **A control apparatus**

Steuergerät

Dispositif de commande

(84) Designated Contracting States:
BE CH DE FR GB IT LI NL

(30) Priority: **04.06.1985 SE 8502756**

(43) Date of publication of application:
22.05.1991 Bulletin 1991/21

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
86107235.3 / 0 204 260

(73) Proprietor: **Gambro Lundia AB**
220 10 Lund (SE)

(72) Inventors:
- **Bjäre, Björn Ake**
  S-222 77 Lund (SE)
- **Eckerbom, Anders Gustav**
  S-161 51 Bromma (SE)
- **Gummesson, Bengt-Ake Göran**
  S-230 40 Bara (SE)
- **Sternby, Jan Peter**
  S-222 52 Lund (SE)

(74) Representative: **Asketorp, Göran et al**
Gambro Lundia AB
Patent Department
Box 10101
220 10 Lund (SE)

(56) References cited:
EP-A- 0 004 905
GB-A- 2 125 577
GB-A- 2 141 838
US-A- 4 153 554

- **"Sicherheitstechnik bei einem mikroprozessorgesteuerten Hämodialysegerät", R. Heitmeier et al., periodical "medizintechnik", vol. 105 4/85, pages 118-124**

EP 0 428 505 B2

Description

FIELD OF INVENTION

[0001] The present invention relates to a method of adjusting a control apparatus and a control apparatus, which are particularly suitable for the control of complex equipment and processes such as hemodialysis or blood purification procedures utilized for treating patients with diminished or nil renal function.

BACKGROUND OF THE INVENTION

[0002] Equipment for hemodialysis has become commonly available in recent years. Particularly reference is made to the systems disclosed in United States Patent Nos. 4 122 010, 4 158 034, 4 293 409, 4 194 974, 4 191 359 and 4 536 201. Additional aspects of hemodialysis equipment and methods are described in British Patent No 2 003 274, and United States Patent No 4 585 552.

[0003] Although the hemodialysis equipment and methods disclosed in the aforementioned patents and applications provide effective treatment modalities, there is a need for still further improvement.

[0004] Hemodialysis processes typically comprises the control of numerous operating parameters, such as, e.g., various fluid temperatures, ultrafiltration rates, ultrafiltrate volumes, transmembrane pressures or pressure differentials across the dialysis membrane itself, and various parameters of fluid flows, such as blood flow to and from the machine, venous pressure, arterial pressure and blood temperature. Each of these parameters may be regulated according to one or more control constants.

[0005] In the simplest form of said regulation, the system may merely monitor deviations of the actual value of the parameter from a set point or desired value and undertake corrective action. Typically, however, upper and lower limits are also provided for some or all of these parameters as an additional safety factor. Thus, the system may monitor the actual value of the parameter in question and generate an alarm signal, where the actual value is outside the range between the upper and lower alarm limits. Accordingly, three different values of the three different control constants - lower limit, set point and upper limit - must be supplied to the control system for each parameter where this scheme is employed.

[0006] The machine operator must therefore enter a large number of different values of different control constants into a computer system to set or adapt the system for desired modes of operation.

[0007] In apparatuses of this nature which has been utilized heretofore, the control panel typically has incorporated a separate, continuously movable maneuvering element such as a control knob or slide for each different control constant to be entered. Arrangements of this nature require a great number of knobs and the like on the control panel, and hence make the control panel confusing and difficult to use. The operator may encounter difficulties in determining which knob or maneuvering element should be adjusted to alter a given function of the system. These difficulties are compounded where the knobs or other control elements are dispersed on the panel, so that a given knob may be remote from the gauge or indicator for the parameter associated with that knob. Such confusion can be inconvenient for the operator and can also present a safety hazard if the wrong control constant is adjusted by mistake.

[0008] Moreover, a further safety hazard can be created if the operator enters the wrong value for a control constant. The operator may mistakenly set a value for an upper alarm limit on a parameter which is orders of magnitude too high, and hence may effectively disable the alarm function of the system. Manifestly, such an error can create a safety hazard, inasmuch as the alarm would not operate even though a potentially dangerous condition exists.

[0009] Where the system incorporates digital microprocessors for comparing the actual values of the various parameters with the associated control constants and initiating appropriate control or alarm action, it is most desirable to use at least two microprocessors including a supervisory microprocessor and a control microprocessor, each microprocessor having a storage register associated therewith. The control constants are stored in the registers associated with each of the microprocessors. The control microprocessor may adjust operation of the system based on a comparison of actual measured values for the various parameters with the appropriate set input value, whereas the supervisory microprocessor compares the actual measured values with the upper and lower limit values and generates an alarm if any parameter varies beyond the essential upper or lower limit. The two microprocessors provide redundancy and hence increased safety.

[0010] US Patent No. 4 153 554 discloses such a system incorporating a control circuit for adjusting the operation of the system based on control transducer values and according to constants provided by front panel controls, such as several potentiometers. The operation of the system is monitored by a monitor circuit based on monitor transducer values of the system. An alarm circuit compares constants provided by said front panel controls with values from the monitor circuit and gives an alarm at fault conditions.

[0011] Moreover, the publication "Sicherheitstechnik bei einem mikroprozessorgesteuerten Hämodialysegerät" by R. Heitmeier et al, in "Medizintechnik " No. 105, year 4/85, discloses a multiprocessor system having a control processor (F-µP) and a supervisory processor (K-µP). A keyboard enters parameter values in parallel to storage registers of the two processor systems.

[0012] There has been a problem heretofore in the operation of redundant microprocessor systems of this nature, where such systems are associated with a control

panel having analog devices such as knobs or other movable maneuvering elements for setting the values of the control constants. Typically, the maneuvering elements are associated with analog electrical devices such as potentiometers, so that the setting of each knob or other maneuvering element must be interpreted and converted into a digital value of the associated control constant by devices such as analog-to-digital converters. Such analog devices and converters typically suffer from certain inaccuracies. These inaccuracies may result in the storage of different values for various control constants in the storage registers associated with the two microprocessors. For example, the set point values supplied to the storage register associated with the control microprocessor by the analog-to-digital converter may be above the upper limit value supplied to the storage register associated with the supervisory microprocessor even though the operator has attempted to select a set point value between the upper and lower limit values. If such a mismatch occurs, adjustment of the system by the control microprocessor will cause the actual value of the operating parameter to rise above the upper limit applied by the supervisory microprocessor, which in turn will cause the supervisory microprocessor to continually signal an alarm condition.

DISCLOSURE OF THE INVENTION

[0013] In order to overcome the above-mentioned drawbacks, there is provided a method of adjusting a control apparatus comprising: at least two microprocessors; a first of said microprocessors being adapted to control certain parameters in relation to first control constants stored in a first storage register associated with said first microprocessor and a second of said microprocessors being adapted to monitor said parameters in relation to second control constants stored in a second storage registers associated with said second microprocessor substantially for supervision of said parameters. Moreover, the control apparatus comprises manually controllable input means for supplying values of said control constants to the respective storage registers.

[0014] According to the invention, the method comprises the steps of operating said input means by an operator for supplying new values for said control constants to be entered into one of said first or second storage register as new control constants; subsequently digitally duplicating said new control constants as entered in said one storage register from this register and entering said duplicated new control constants into another of said storage registers, whereby identical values for said new control constants are entered into all of said storage registers; and finally displaying said duplicated new control constants for providing a feedback to the operator.

[0015] Preferably, the method further comprises the steps of checking and possibly amending said new values supplied by said input means to be within predetermined limit values before being approved and entered into said one storage register as new control constants.

[0016] Moreover, there is provided a control apparatus comprising at least two microprocessors, whereby a first of said microprocessors being adapted to control certain parameters in relation to first control constants stored in a first storage register associated with said first microprocessor, and a second of said microprocessors being adapted to monitor said parameters in relation to second control constants stored in a second storage registers associated with said second microprocessor substantially for supervision of said parameters, and further comprising manually controllable input means for supplying values of said control constants to the respective storage registers.

[0017] According to the invention, said input means is adapted to be operated by an operator for supplying new values for said control constants to be entered into one of said first or second storage register, as new control constants; and the control apparatus further comprising digital duplication means for subsequently digitally duplicating said new control constants as entered in said one storage register from this register and entering said duplicated new control constants into another of said storage registers, whereby identical values for said new control constants are entered into all of said storage registers; and display means for finally displaying said duplicated new control constants for providing a feed back to the operator.

[0018] According to a preferred embodiment, the control apparatus includes means for checking and possibly amending said new values supplied by said input means to be within predetermined limit values before being approved and entered into said one storage register as new control constants.

[0019] Because each new value is duplicated digitally from the input register and then duplicated to the other register rather than read separately from an analog element of the input means for entry into each storage register, identical values are always entered into all of the registers. Thus, errors in the analog-to-digital conversion apparatus and other elements associated with the input means cannot result in storage of different values for the control constants in the storage registers associated with the various microprocessors.

[0020] As the operator adjusts the value of each parameter, he naturally observes the display means to determine the value which he has set. Because the displayed value will be the value actually stored in the storage register, after introduction of any errors by the input means, the operator's natural action in observing the displayed values and continuing the adjustment until the desired value is displayed, will automatically compensate for any errors introduced by the input means. Thus, errors caused by the input means will not result in storage of incompatible values for the different control constants, such as incompatible set points and limits. The

digital duplication means may be arranged to copy the new values from the storage register associated with the supervisory microprocessor into the storage register associated with the control microprocessor.

[0021] These and other objects, features, and advantages of the present invention will be more readily apparent from the detailed description of the preferred embodiment set forth below, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0022] Fig. 1 is a schematic front view of a control panel for a system controlling two parameters or variables.

[0023] Figs. 2-4 are views similar to Fig. 1, depicting the same panel in different operating states.

[0024] Fig 5. is a view similar to Fig. 1 but depicting a larger panel according to the present invention for control of a plurality of different parameters in a dialysis system.

[0025] Fig 6. is a schematic functional diagram of the elements in a system incorporating the control panel of Figs. 1-4.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0026] Figs. 1-4 show a control panel which is arranged for the control of two variables or parameters in a dialysis system which includes a dialyzer, a dialysis fluid inlet line, a dialysis fluid outlet line and a dialysis fluid bypass line for directly connecting the inlet line to the outlet line, and hence bypassing the dialyzer.

[0027] The control panel, as illustrated in Figs. 1-4, includes a pictorial representation of the actual fluid flow path in the system, and hence includes a pictorial element 1 representing the dialyzer, pictorial elements 2 and 2a representing the fluid inlet lines to the dialyzer, and pictorial elements 3 and 3a representing the fluid outlet lines. Also, a pictorial representation 4 depicts a bypass line.

[0028] A bypass alarm signal light 5 is provided between the pictorial representation 4 of the bypass line and the pictorial representation 1 of the dialyzer itself. A single manually rotatable knob or maneuvering element 6 is disposed on the front surface of the panel.

[0029] Two graphic displays 9 and 10 are also provided, with each such display being associated with one operating parameter of the system. Display 9 is thus associated with a parameter denominated "xxx", which pertains to the conditions prevailing at the inlet conduit 2, and graphic display 10 is associated with a parameter denominated "yyy," which pertains to the conditions prevailing at the outlet conduit 3. Graphic display 9 is disposed adjacent inlet conduit 2 and includes a common linear scale 9a with associated numerals. The display also includes illuminated indicia 7a, 7c and 7d, representing the values of control constants for parameter xxx, in this case the set point represented by indicia 7a, the lower limit represented by indicia 7c, and the upper limit represented by indicia 7d. The positions of these indicia along scale 9a represent the values of these control constants.

[0030] Graphic display 9 also includes a bar display 7b for displaying the actual measured value of parameter xxx. The length of bar 7b, and hence the position of the right hand edge of the bar along scale 9a represents the actual value of parameter xxx. A manually operable actuator or button 7, marked with the name of the parameter or "xxx", is disposed adjacent display 9.

[0031] In a similar fashion, the display 10 for parameter yyy, pertaining to the outlet conduit of the system, is disposed adjacent the pictorial representation 3 of the outlet conduit. Display 10 is generally similar to display 9, and includes a scale IOa, illuminated indicators 8a, 8c and 8d for displaying the set point, lower limit and upper limit for parameter yyy, and a bar graph 8b for indicating the actual value of parameter yyy. An actuator 8 is disposed adjacent display 10 and is labeled with the name of the associated parameter yyy.

[0032] Also arranged on the front of the control panel are control constant selector buttons 12, which include an upper limit selector button 12' and a lower limit selector button 12", both disposed adjacent manually rotatable knob or maneuvering element 6. An alphanumeric display 11 is disposed on the panel face immediately above knob 6.

[0033] As illustrated in Fig. 6, actuators 7 and 8 are linked to parameter selection means 31, which in turn is connected to interpretation means 32. Maneuvering element knob 6 is linked to a potentiometer 34, which in turn is connected to an analog-to-digital converter 36. Converter 36 is also connected to interpretation apparatus 32. Control constant selector buttons 12' and 12" are linked to control constant selection means 38 which is also linked to interpretation means 32. Interpretation means 32 is in turn connected to a comparison and substitution apparatus 40, which is linked to a bounding value storage register 42.

[0034] As explained below, these components provide new values of the control constants to the control system. The control system includes a supervisory microprocessor 44 incorporating a storage register 46 and duplication means 48. The control system also includes a control microprocessor 50 incorporating a further storage register 52. Both of the microprocessors are linked to transducers 54 arranged to measure the actual values of the various operating parameters of the actual system. Supervisory microprocessor 44 is arranged to control graphic displays 9 and 10 and bypass alarm 5. The supervisory microprocessor is also arranged to control pictorial illumination unit 56 so as to selectively illuminate each segment of the pictorial representation 1, 2, 2a, 3, 3a and 4 with red light or with green light, as instructed by the supervisory micro-processor, or to leave each segment unilluminated. The supervisory mi-

croprocessor is also connected, via appropriate drivers (not shown) to illuminators 58 and 60 disposed physically within actuator buttons 7 and 8.

[0035] The control microprocessor 50 is linked to alphanumeric display 11, and is also to linked to the adjustable element 62 of the dialyzer and associated flow conduits. These adjustable elements typically include valves, variable electric resistance heaters, and the like.

[0036] Although parameter selection means 31, interpretation means 32, control constant selection means 38, analog-to-digital converter 36, bounding value storage means 42, and comparison and substitution means 40 are illustrated in Figs. 6 as being separate from the microprocessors, it should be clearly understood that such depiction is solely for the sake of clarity of illustration. In actual practice, some or all of these elements can actually be incorporated in one or both of the microprocessors.

[0037] Figure 1 illustrates the condition of the panel face during normal operation, without adjustment of any of the control constants. In this condition, illuminators 58 and 60 (Fig. 6) are inactive, so that actuator buttons 7 and 8 are not illuminated. Pictorial illumination means 36 (Fig. 6) illuminates the pictorial representations of the dialyzer 1, the inlet conduits 2 and 2a, and the outlet conduits 3 and 3a with green light, and leaves the pictorial representation 4 of the bypass conduit unilluminated. The bypass alarm light 5 is likewise unilluminated. Alphanumeric display 11 is blank, and graphic display 9 is actuated to display the values of set point, lower limit and upper limit for parameter xxx stored in the storage register 46 of the supervisory microprocessor 44, and also to display the actual value of parameter xxx as measured by the transducers 54. Likewise, graphic display 10 displays the set point, lower limit and upper limit for parameter yyy, also as stored in register 46, and also displays the actual value of parameter yyy.

[0038] During normal operation, the actual value of each parameter is close to its set point and within the range defined by the upper and lower limits for this parameter. Inasmuch as the set point, actual value and limits for each parameter are clearly displayed along a common scale on a single graphic display, normal operation of the system is readily verifiable and the system condition as a whole can be readily determined by mere visual inspection of the panel.

[0039] Figure 2 illustrates the condition of the panel during adjustment by the operator of the set point for parameter yyy. Upon manual actuation by the operator of actuator or button 8 associated with parameter yyy, parameter selection means 31 selects parameter yyy. This selection is conveyed to supervisory microprocessor 44, which in turn instructs graphic display to flash the illuminated indicia 8a, 8c and 8d, for the control constants associated with parameter yyy.

[0040] In the condition illustrated, the operator has not depressed either upper limit selector button 12' or lower limit selector button 12". Accordingly, control constant selection means 38 selects the set point for parameter yyy, rather than the upper limit or lower limit for that parameter as the particular control constant to be adjusted, and signals interpretation means accordingly. The interpretation means thus interprets the manually variable signal generated by manual adjustment of maneuvering element or knob 6 and operation of analog-to-digital converter 36 as a new value for the set point for parameter yyy.

[0041] The new value of parameter yyy is passed to comparison and substitution means 40. The comparison and substitution means compares the new value with preset, invariant upper and lower bounding values for the set point of parameter yyy stored in bounding value storage means 42. If the new value of the set point generated by interpretation means 32 is outside the range defined by these bounding values, then the comparison and substitution means 40 would substitute a value within such a range for the new value generated by the interpretation means.

[0042] In the situation illustrated in Figure 2, however, the new value generated by the interpretation means is within this range, so that the new value passes unaltered from the interpretation means to the supervisory microprocessor 44.

[0043] Microprocessor 44 is arranged so that the new values are entered into register 46 and then copied from that register by duplication means 48 into register 52. Control microprocessor 50 drives alphanumeric display 11 to show both the actual measured value of parameter yyy, as obtained from transducers 54, and also to show the value of the set point for this parameter last entered into register 52. Because the values of the set point are duplicated digitally, the exact same value will be stored in register 46 and in register 52. Moreover, because the value as stored in register 52 is fed back to the operator via alphanumeric display 11, as illustrated in Fig. 2, the operator will control his actuation of knob 6 according to the set point values as actually input into the storage registers. Accordingly, inaccuracies in potentiometer 34 or analog-to-digital converter 36 are of little consequence. Such errors will not result either in the storage of divergent values in the two storage registers 46 and 52, or in the storage of incorrect values. Also, if the operator attempts to set an incorrect value such that the comparison and substitution means replaces the manually set value with one of the preset bounding means, the bounding limit rather than the manually set value will be displayed on display 11. Accordingly, the displayed value will not change as the operator adjusts the knob further in the wrong direction, thus warning the operator of his error. Additional indications of such an error can also be provided.

[0044] During the setting process, the supervisory microprocessor adjusts the position of the indicia 8a for the set point along the scale 10a of display 10, so as to reflect the new set point value. As the set point is thus adjusted, and thereafter, the control microprocessor 50

will compare the actual value of parameter yyy from the transducers from the new set point and will adjust the system adjuster components 62 to drive the actual value of this parameter towards the set point value.

[0045] When upper alarm limit selector button 12' is depressed, the control constant selection means 38 selects the upper limit control constant for adjustment. Thus, if the upper limit selection button 12' is actuated in conjunction with parameter selection button 8, the interpretation means will interpret these signals derived from manually adjustable maneuvering element or knob 8 via potentiometer 34 and converter 36 as a new value for the upper limit of parameter yyy. In that event, the comparison and substitution means will compare the new value with bounding values appropriate to the upper limit, rather than to the set point for parameter yyy and control microprocessor 50 will cause alphanumeric display 11 to display both the actual value of parameter yyy and the new upper limit value input into and stored in register 52.

[0046] Likewise, with combined actuation of parameter selection button 8 and lower limit selection button 12", the variable signal derived from operation of knob 6 will be interpreted as a new value for the lower limit of parameter yyy.

[0047] As will be appreciated, the same action pertains to the setting of those parameters which requires actuation of button 7, rather than button 8. In each case, the signal derived from operation of knob 6 is interpreted as a new value for the particular control constant selected by the control constant selection means for the particular parameter selected by the parameter selection means. The identity of the parameter and of the control constant being set is displayed, along with the value of the constant as set, on alphanumeric display 11.

[0048] Figure 3 illustrates the appearance of the front panel when parameter yyy falls outside the upper and lower limits associated with that parameter, and the control microprocessor adjusts the system to bypass the dialyzer. The bar graph 8b reflecting the actual measured value of parameter yyy shows the out-of-limit value. Thus, the right hand edge of the bar graph is at a low level on the scale IOa and is outside the range encompassed by indicia 8a and 8d, corresponding to the lower and upper limits, respectively.

[0049] To provide a conspicuous alarm signal indicating that parameter yyy is outside of the limits, supervisory microprocessor 44 (Fig. 6) causes illuminator 60 to illuminate actuator 8 with a red light. At the same time, the supervisory microprocessor illuminates bypass alarm indicator 5. The supervisory microprocessor also adjusts pictorial illumination means 56 to illuminate the pictorial representation 2 of the inlet conduit, the pictorial representation 4 of the bypass conduit, and the pictorial representation 3 of the outlet conduit with a red light. The pictorial representations 2a and 3a of the branch conduits leading to and from the dialyzer are left unilluminated. These pictorial representations thus instantly inform the operator that the system is in a bypass condition. The red color of the illuminated representation provides a further signal that the bypass condition is the result of an abnormal, out-of-limit condition. These signals are supplemented by the bypass alarm light 5. The alarm indication provided by illuminated actuator 8 guides the operator to instant identification of the particular parameter which is out-of limits, and which has caused the abnormal condition.

[0050] Because all of the actual values and control constants for the various parameters are continually displayed on the associated graphic displays, the operator can promptly diagnose the nature of the malfunction.

[0051] As is illustrated in Figure 4, the system may be deliberately switched into a bypass mode, for example as part of a predetermined schedule of operation, and this can be done even where none of the parameters is in an out-of-limit condition. In this case, the illuminators associated with actuators 7 and 8 are left unilluminated, so that no alarm signal is given.

[0052] Also, although the pictorial representation means is adjusted by the supervisory microprocessor to illuminate pictorial representations 2, 3 and 4 to show the bypass flow, and to leave representations 2a and 3a unilluminated to show that no flow is going through the dialyzer, the pictorial representation is illuminated in green light, rather than red light. Thus, whether or not there is an alarm condition, the pictorial representation can be employed to show the actual flow path in use within the system.

[0053] Typically, the systems controlled by the apparatus in accordance with the present invention require control of more than two parameters, as is employed in the system of Figs. 1-4. Figure 5 thus depicts the front face of a control panel, as can be used in controlling dialysis fluid flow in a hemodialysis system. The panel of Fig. 5 incorporates the same elements as mentioned above in connection with Figs. 1-4 and 6. Elements common to both embodiments are denoted in Fig. 5 by the same reference numerals as those employed in Figs. 1-4 and 6. However, display 9 is associated in Fig. 5 with the real parameter of fluid conductivity, and the associated adjacent actuator 7 is marked with the legend "COND", rather than with the nominal legend "xxx" appearing on the corresponding actuator appearing in Fig. 2. Likewise, the graphic display 10 is associated with the real parameter transmembrane pressure, and the associated adjacent actuator 8 is marked with the legend "TMP", rather than with the nominal legend "yyy," as in the other figures.

[0054] The pictorial representation on the front face of the panel in Fig. 5 includes the same elements as the pictorial representation of Figs. 1-4, but also includes a pictorial representation 13 of an additional branch conduit carrying an ultrafiltrate flow. Additional graphic representations 22 and 23 associated with ultrafiltrate volume and ultrafiltration rate parameters, both of which pertain to the flow in the ultrafiltrate conduit represented

by branch 13, are disposed on the panel front face adjacent this branch of the pictorial representation. Actuators 18 and 19 which are associated, respectively, with ultrafiltrate volume and ultrafiltration rate, are disposed adjacent to graphic displays 22 and 23, respectively.

[0055] Furthermore, additional graphic displays 20 and 21 for incoming dialysis fluid temperature in the inlet represented by pictorial representation 2, and fluid flow in the inlet 2, respectively, are disposed adjacent to the pictorial representation of the inlet conduit. Actuators 14 and 15 relating to these parameters are disposed adjacent to these additional displays.

[0056] The panel of Fig. 5 incorporates additional buttons 26 for setting the system to operate in different modes. Thus, each of these buttons may be linked to the control and supervisory microprocessors of the system, so that these microprocessors, and hence the system as a whole, can operate according to different programs, depending upon which of the buttons is actuated. For example, depression of the button 26 marked "TMP Mode" sets the system to operate so as to maintain the transmembrane pressure constant, whereas operation of the button 26 marked "Auto UF Mode" sets the system to perform a dialysis procedure with accurately controlled ultrafiltration. Operation of the button marked "Isolated UF Mode" sets the system to perform a pure ultrafiltration procedure without any dialysis fluid flow. Likewise, the buttons marked "HEAT DISNF", "CHEM DISNF", "RINSE" and "DRAIN" sets the system to perform the corresponding heat sterilization, chemical sterilization, rinsing or emptying of functions.

[0057] The panel of Fig. 5 also includes a clock display 27. This clock display is associated with and adjacent to an actuator 16 marked "TIME". Operation of this actuator combined with adjustment of the knob or maneuvering element 6 sets the time of internal clocks within the microprocessors of the system.

[0058] The panel of Fig. 5 also includes additional displays for showing information other than the values and control constants for the parameters set from the panel. Thus, digital display 28 marked "WATER LEV" indicates the fluid level in a vessel for containing dialysis fluid. The panel of Fig. 5 also includes a start button 24 and a button 25 marked "CONFIRM" disposed adjacent maneuvering element or knob 6.

[0059] Operation of the panel shown in Fig. 5 is substantially the same as operation of the panel described above with reference to Figs. 1-4 and 6. Thus, to set the upper limit for transmembrane pressure, the operator actuates actuator 8 adjacent display 10 for transmembrane pressure, and also actuates the high limit button 12' adjacent to maneuvering element or knob 6. The variable signal produced upon actuation of this element is interpreted as a new value for the transmembrane pressure upper limit, which is displayed on alphanumeric display 11. However, in operation of the panel according to Fig. 5, the control system does not begin to apply the new value so set until the operator signals that he is satisfied with the new value displayed on display 11 by pressing CONFIRM button 25. To permit this function, each of the storage registers associated with the microprocessors may be provided with a temporary storage location, distinct from the storage locations for the parameters actually in use, and each microprocessor may be arranged to shift the newly set value from the temporary storage location to the storage location assigned to the parameter when the CONFIRM button is depressed.

[0060] Numerous variations and combinations of the features described above can be employed in accordance with the present invention. Thus, in one variant of the invention, the upper and lower limits are not set directly. Instead, the system is arranged to calculate upper and lower limits for each parameter from the set point selected by the operator for such parameter. The upper and lower limits may be calculated from the set point according to a predetermined formula or algorithm. In this case, the control constant selection means may be omitted and the high limit and low limit selector buttons 12' and 12" may likewise be omitted.

[0061] Also, the layout of the fluid flow path and the control panel face may make it impossible to dispose each graphic display and the associated actuator immediately adjacent the pictorial representation of the pertinent portion of the fluid flow path. Thus, some of the graphic displays may be disposed adjacent related pictorial representations, whereas other graphic displays may be disposed at more remote locations.

[0062] In less preferred embodiments, the pictorial representation may be omitted entirely, and the graphic displays may be replaced by other forms of display. In another less preferred embodiment, alphanumeric display 11 may be omitted entirely, and the supervisory microprocessor may be arranged to display the new value set for each control constant only on the related graphic display.

[0063] As will be readily appreciated, the layout of the panel face, and the particular parameters and actual constants employed, will vary with the nature of the system to be controlled.

[0064] Typically, in control of the dialysis fluid portion of a hemodialysis system, the control panel should be arranged to set control constants for one or more of the following functions: conductivity, temperature, fluid flow, transmembrane pressure, ultrafiltrate volume, ultrafiltration rate, time, chemical composition, pH and blood leakage monitoring.

[0065] In control of the bloodhandling portion of a hemodialysis system, control constants for one or more of the following parameters should be set by use of a control panel in accordance with the present invention: temperature, blood flow, transmembrane pressure, venous pressure, arterial pressure, chemical composition and the presence of air.

[0066] In a particularly preferred arrangement, the control panel according to the present invention is con-

figured to control both blood handling portion and the hemodialysis fluid flow portion of the system. A control panel for such use would typically incorporate pictorial representations of the flow paths for both blood and dialysis fluid. As the present invention provides important improvements in monitoring and control of operating parameters in hemodialysis fluid flow and/or blood flow in hemodialysis operations, the invention provides improved methods of controlling these functions. In the improved methods, control panels and systems in accordance with the present invention are employed and operated as described above.

[0067] In the apparatus described above, the comparison and substitution means checks the new value for every control constant. However, the apparatus can be arranged so that the less significant or noncritical control constants are not so checked.

Claims

1. A method of adjusting a control apparatus comprising:

   at least two microprocessors;
   a first of said microprocessors being adapted to control certain parameters in relation to first control constants stored in a first storage register associated with said first microprocessor;
   a second of said microprocessors being adapted to monitor said parameters in relation to second control constants stored in a second storage registers associated with said second microprocessor substantially for supervision of said parameters;
   manually controllable input means for supplying values of said control constants to the respective storage registers;

   characterized in

   operating said input means by an operator for supplying new values for said control constants to be entered into one of said first or second storage register as new control constants;
   subsequently digitally duplicating said new control constants as entered in said one storage register from this register and entering said duplicated new control constants into another of said storage registers, whereby identical values for said new control constants are entered into all of said storage registers; and
   finally displaying said duplicated new control constants for providing a feedback to the operator.

2. Method according to claim 1, **characterized** in checking and possibly amending said new values supplied by said input means to be within predetermined limit values before being approved and entered into said one storage register as new control constants.

3. Method according to claim 1 or 2, **characterized** in measuring said parameters by first transducers associated with said first microprocessor and by second transducers associated with said second microprocessor, and independently comparing said measured parameter values with said control constants stored in the associated storage register.

4. Method according to claim 3, wherein said parameters are influenced upon by adjustable elements, **characterized** in comparing a sample of one parameter taken by the associated first transducer, with said control constants stored in said storage register, and providing a control signal to said adjustment elements for adjusting said parameter to a value given by said control constants and/or to be within certain limit values given by said control constants and in that said second microprocessor is adapted to compare a sample taken by the associated second transducer with said control constants stored in said second storage register, for providing an alarm signal when said sample is outside said limit values given by said control constants.

5. Control apparatus intended for performing the method according to anyone of claims 1 - 4, comprising:

   at least two microprocessors (44,50);
   a first of said microprocessors (50) being adapted to control certain parameters (xxx,yyy) in relation to first control constants stored in a first storage register (52) associated with said first microprocessor;
   a second of said microprocessors (44) being adapted to monitor said parameters in relation to second control constants stored in a second storage registers (46) associated with said second microprocessor substantially for supervision of said parameters;
   manually controllable input means (6) for supplying values of said control constants to the respective storage registers;

   characterized in that

   said input means (6) is adapted to be operated by an operator for supplying new values for said control constants to be entered into one of said first or second storage register (46,52), as new control constants;
   digital duplication means (48) for subsequently digitally duplicating said new control constants

as entered in said one storage register from this register and entering said duplicated new control constants into another of said storage registers (46,52), whereby identical values for said new control constants are entered into all of said storage registers; and
display means (11) for finally displaying said duplicated new control constants for providing a feed back to the operator.

6. Control apparatus according to claim 5, **characterized** by means (40,42) for checking and possibly amending said new values supplied by said input means to be within predetermined limit values before being approved and entered into said one storage register as new control constants.

7. Control apparatus according to claim 5 or 6, **characterized** in that said parameters are measured by first transducers (54) associated with said first microprocessor and by second transducers (54) associated with said second microprocessor, said microprocessors being adapted to independently compare said measured parameter values with said control constants stored in the associated storage register.

8. Control apparatus according to claim 6 or 7, wherein said parameters are influenced upon by adjustable elements (62), **characterized** in that said first microprocessor is adapted to compare a sample of one parameter taken by the associated first transducer, with said control constants stored in said storage register, and providing a control signal to said actuation means for adjusting said parameter to a value given by said control constants and/or to be within certain limit values given by said control constants and in that said second microprocessor is adapted to compare a sample taken by the associated second sensor with said control constants stored in said second storage register, for providing an alarm signal (5) when said sample is outside said limit values given by said control constants.

9. Control apparatus according to anyone of claims 5 - 8, **characterized** in that said digital duplication means (48) is incorporated into one (44) of said microprocessors (44,50).

10. Control apparatus according to anyone of claims 5-9, **characterized** in that said parameter is selected from the group consisting of conductivity, temperature, fluid flow, transmembrane pressure, ultrafiltrate volume, ultrafiltration rate, time, chemical composition, pH, and blood leakage.

Patentansprüche

1. Verfahren zum Einstellen einer Steuervorrichtung mit:

einem ersten Mikroprozessor, der geeignet ausgestaltete ist, um gewisse Parameter in Beziehung zu ersten Steuerkonstanten zu steuern, die in einem ersten Speicherregister gespeichert sind, welches dem ersten Mikroprozessor zugeordnet ist;
einem zweiten Mikroprozessor, der geeignet ausgestaltet ist, um die Parameter zu überwachen im Verhältnis zu zweiten Steuerkonstanten, die in einem zweiten Steuerregister gespeichert sind, welches dem zweiten Mikroprozessor zugeordnet ist, im wesentlichen für die Überwachung der Parameter;
von Hand steuerbaren Eingangsmitteln für die Zuführung von Werten der Steuerkonstanten zu den entsprechenden Speicherregistern;

gekennzeichnet durch

Betreiben des Eingangsmittels durch einen Bedienungsmann für das Zuführen neuer Werte für die Steuerkonstanten, die in eines der ersten oder zweiten Speicherregister als neue Steuerkonstanten eingeführt werden sollen;
danach digitales Vervielfältigen der neuen Steuerkonstanten, wie sie aus diesem Register in das eine Speicherregister eingegeben sind, und Eingeben der vervielfältigten neuen Steuerkonstanten in ein anderes Speicherregister, wobei identische Werte für die neuen Steuerkonstanten in alle Speicherregister eingegeben werden; und
schließlich Anzeigen der vervielfältigten neuen Steuerkonstanten für die Schaffung einer Rückführung zu dem Bedienungsmann.

2. Verfahren nach Anspruch 1, **gekennzeichnet** durch das Prüfen und möglicherweise Verbessern der neuen Werte, welche von dem Eingangsmittel zugeführt sind, damit sie in vorbestimmten Grenzwerten liegen, bevor sie genehmigt und in das eine Speicherregister als neue Steuerkonstanten eingegeben werden.

3. Verfahren nach Anspruch 1 oder 2, **gekennzeichnet** durch Messen der Parameter durch erste Wandler, welche dem ersten Mikroprozessor zugeordnet sind, und durch zweite Wandler, welche dem zweiten Mikroprozessor zugeordnet sind, und unabhängiges Vergleichen der gemessenen Parameterwerte mit den Steuerkonstanten, die in dem zugeordneten Speicherregister gespeichert sind.

4. Verfahren nach Anspruch 3, wobei die Parameter durch einstellbare Elemente beeinflußt werden, **gekennzeichnet** durch das Vergleichen einer Probe eines Parameters, der von dem zugeordneten ersten Wandler aufgenommen ist, mit den Steuerkonstanten, die in dem Speicherregister gespeichert sind, und Schaffen eines Steuersignales zu den Einstellelementen für das Einstellen des Parameters auf einen Wert, der von den Steuerkonstanten gegeben ist und/oder für das Liegen innerhalb gewisser Grenzwerte, welche durch die Steuerkonstanten gegeben sind, und dadurch **gekennzeichnet**, daß der zweite Mikroprozessor geeignet ausgestaltet ist, eine Probe, die von dem zugeordneten zweiten Wandler genommen ist, mit den Steuerkonstanten zu vergleichen, die in dem zweiten Speicherregister gespeichert sind, zur Schaffung eines Alarmsignals, wenn die Probe außerhalb von Grenzwerten liegt, welche durch die Steuerkonstanten gegeben sind.

5. Steuervorrichtung zur Durchführung des Verfahrens nach einem der Ansprüche 1 - 4, mit:

mindestens zwei Mikroprozessoren (44, 50);
wobei ein erster Mikroprozessor (50) geeignet ausgestaltet ist, um gewisse Parameter (xxx, yyy) im Verhältnis zu ersten Steuerkonstanten zu steuern, die in einem ersten Speicherregister (52) gespeichert sind, welches dem ersten Mikroprozessor zugeordnet ist;
einem zweiten Mikroprozessor (44), der geeignet ausgestaltet ist, um die Parameter im Verhältnis zu zweiten Steuerkonstanten zu überwachen, die in einem zweiten Speicherregister (46) gespeichert sind, welches dem zweiten Mikroprozessor zugeordnet ist, im wesentlichen für die Überwachung der Parameter;
von Hand steuerbaren Eingabemitteln (6) für die Zuführung von Werten der Steuerkonstanten zu den betreffenden Speicherregistern;

dadurch gekennzeichnet, daß

Eingabemittel (6) geeignet ausgestaltet sind, um von einem Bedienungsmann betrieben zu werden für die Zuführung neuer Werte für die Steuerkonstanten, die in eines der ersten oder zweiten Speicherregister (46, 52) einzugeben sind, als neue Steuerkonstanten;
digitale Vervielfältigungsmittel (48) vorgesehen sind für das danach erfolgende digitale Vervielfältigen der neuen Steuerkonstanten, wie sie aus diesem Register in das eine Speicherregister eingegeben sind, und Eingeben der vervielfältigten neuen Steuerkonstanten in ein anderes Speicherregister (46, 52), wodurch identische Werte für die neuen Steuerkonstanten in alle Speicherregister eingegeben werden; und
Anzeigemittel (11) vorgesehen sind für die Anzeige der vervielfältigten neuen Steuerkonstanten zur Schaffung einer Rückführung zu dem Bedienungsmann.

6. Steuervorrichtung nach Anspruch 5, **gekennzeichnet** durch Mittel (40, 42) zum Prüfen und möglicherweise Verbessern der neuen Werte, welche von dem Eingangsmittel zugeführt sind, damit sie in vorbestimmten Grenzwerten liegen, bevor sie genehmigt und in das Speicherregister als neue Steuerkonstanten eingegeben werden.

7. Steuervorrichtung nach Anspruch 5 oder 5, **dadurch gekennzeichnet**, daß die Parameter durch erste Wandler (54) gemessen werden, welche dem ersten Mikroprozessor zugeordnet sind, und von zweiten Wandlern (54), welche dem zweiten Mikroprozessor zugeordnet sind, wobei die Mikroprozessoren geeignet ausgestaltet sind, um unabhängig die gemessenen Parameterwerte mit den Steuerkonstanten zu vergleichen, die in dem zugeordneten Speicherregister gespeichert sind.

8. Steuervorrichtung nach Anspruch 6 oder 7, wobei die Parameter durch einstellbare Elemente (62) beeinflußt werden, dadurch **gekennzeichnet**, daß der erste Mikroprozessor geeignet ausgestaltet ist, eine Probe eines Parameters, der von dem zugeordneten ersten Wandler aufgenommen ist, mit den Steuerkonstanten zu vergleichen, die in dem Speicherregister gespeichert sind, und daß ein Steuersignal zu dem Betätigungsmittel vorgesehen wird für das Einstellen des Parameters auf einen Wert, welcher durch die Steuerkonstanten gegeben ist und/oder dafür, sich in bestimmten Grenzwerten zu befinden, welche von den Steuerkonstanten gegeben sind, und daß der zweite Mikroprozessor geeignet ausgestaltet ist, eine Probe, die von dem zugeordneten zweiten Sensor aufgenommen ist, mit den Steuerkonstanten zu vergleichen, welche in dem zweiten Speicherregister gespeichert sind, zur Schaffung eines Alarmsignals (5), wenn die Probe außerhalb der Grenzwerte liegt, welche durch die Steuerkonstanten gegeben sind.

9. Steuervorrichtung nach einem der Ansprüche 5 - 8, dadurch **gekennzeichnet**, daß das digitale Vervielfältigungsmittel (48) in einen (44) der Mikroprozessoren (44, 50) inkorporiert ist.

10. Steuervorrichtung nach einem der Ansprüche 5 - 9, dadurch **gekennzeichnet**, daß der Parameter aus der Gruppe ausgewählt wird, die aus Leitfähigkeit, Temperatur, Fluidfluß, Transmembrandruck, Ultrafiltratvolumen, Ultrafiltrationsgeschwindigkeit, Zeit, chemische Zusammensetzung, pH und Blutlecka-

ge besteht.

Revendications

1. Procédé de mise au point de valeurs pour un appareil de réglage comprenant :

   au moins deux microprocesseurs,
   un premier de ces microprocesseurs étant agencé de façon à régler certains paramètres, en liaison avec des premières constantes de réglage rangées dans un premier registre de mémoire associé au premier microprocesseur,
   un second desdits microprocesseurs étant agencé de façon à surveiller lesdits paramètres en liaison avec des secondes constantes de réglage rangées dans un second registre de mémoire associé au second microprocesseur, essentiellement en vue de superviser lesdits paramètres,
   des moyens d'entrée réglables manuellement servant à envoyer des valeurs desdites constantes de réglage aux registres de mémoire respectifs,

   caractérisé en ce qu'il comprend les opérations consistant :

   à faire actionner les moyens d'entrée par un opérateur de façon que de nouvelles valeurs correspondant aux constantes de réglage à introduire soient envoyées, en tant que nouvelles constantes de réglage, dans l'un des registres constitués par le premier registre de mémoire et le second registre de mémoire,
   à procéder ensuite à une duplication numérique des nouvelles constantes de réglage telles qu'entrées dans ledit premier registre de mémoire à partir de ce registre et à introduire dans un autre des registres de mémoire les nouvelles constantes de réglage obtenues par duplication, de sorte que ce sont des valeurs identiques des nouvelles constantes de réglage qui sont introduites dans tous les registres de mémoire,
   et à réaliser finalement une visualisation des nouvelles constantes de réglage obtenues par duplication, de façon à offrir une rétroaction à l'opérateur.

2. Procédé selon la revendication 1, caractérisé en ce qu'il comprend en outre les opérations consistant à contrôler les nouvelles valeurs fournies par les moyens d'entrée et éventuellement à les corriger de façon qu'elles soient situées entre des valeurs limites préfixées, avant qu'elles soient approuvées et introduites dans le premier registre de mémoire en tant que nouvelles constantes de réglage.

3. Procédé selon la revendication 1 ou 2, caractérisé en ce qu'il comprend les opérations consistant à mesurer lesdits paramètres au moyen de premiers transducteurs associés au premier microprocesseur et au moyen de seconds transducteurs associés au second microprocesseur et à comparer d'une manière indépendante les valeurs de paramètre, mesurées, aux constantes de réglage rangées dans le registre de mémoire associé.

4. Procédé selon la revendication 3, selon lequel des éléments réglables influent sur lesdits paramètres, caractérisé en ce qu'il comprend les opérations consistant à comparer un échantillon d'un paramètre donné, prélevé par le premier transducteur associé, aux constantes de réglage rangées dans ledit registre de mémoire et à envoyer aux éléments réglables un signal de réglage permettant de régler ledit paramètre de façon qu'il prenne une valeur donnée par les constantes de réglage et/ou de façon qu'il soit compris entre certaines valeurs limites données par les constantes de réglage et en ce que le second microprocesseur est agencé de façon à comparer un échantillon prélevé par le second transducteur associé, aux constantes de réglage rangées dans le second registre de mémoire, de façon à fournier un signal d'alarme lorsque l'échantillon est situé en dehors des valeurs limites données par les constantes de réglage.

5. Appareil de réglage permettant de mettre en oeuvre un procédé selon l'une des revendications 1 à 4, comprenant :

   au moins deux microprocesseurs (44, 50),
   un premier de ces microprocesseurs (50) étant agencé de façon à régler certains paramètres (XXX, YYY) en liaison avec des premières constantes de réglage rangées dans un premier registre de mémoire (52) associé au premier microprocesseur,
   un second desdits microprocesseurs (44) étant agencé de façon à surveiller lesdits paramètres en liaison avec des secondes constantes de réglage rangées dans un second registre de mémoire (46) associé au second microprocesseur, essentiellement en vue de superviser lesdits paramètres,
   des moyens d'entrée (6) réglables manuellement servant à envoyer des valeurs desdites constantes de réglage aux registres de mémoire respectifs,

   caractérisé en ce que :

   les moyens d'entrée (6) sont agencés de ma-

nière à être actionnés par un opérateur de façon que de nouvelles valeurs des constantes de réglage à introduire soient envoyées, en tant que nouvelles constantes de réglage, dans l'un des registres constitués par le premier registre de mémoire et le second registre de mémoire (46-52),
des moyens de duplication numérique (48) servant à réaliser ensuite une duplication numérique des nouvelles constantes de réglage telles qu'entrées dans ledit premier registre de mémoire à partir de ce registre et à introduire dans un autre des registres de mémoire (46-52) les nouvelles constantes de réglage obtenues par duplication, de sorte que ce sont des valeurs identiques des nouvelles constantes de réglage qui sont introduites dans tous les registres de mémoire, et
des moyens de visualisation (11) permettant finalement de visualiser les nouvelles constantes de réglage obtenues par duplication, de façon à offrir une rétroaction à l'opérateur.

6. Appareil de réglage selon la revendication 5, caractérisé par des moyens (40, 42) servant à contrôler les nouvelles valeurs fournies par les moyens d'entrée, et éventuellement les corriger de façon qu'elles soient situées entre des valeurs limites préfixées, avant qu'elles soient approuvées et introduites dans le premier registre de mémoire en tant que nouvelles constantes de réglage.

7. Appareil de réglage selon la revendication 5 ou 6, caractérisé en ce que lesdits paramètres sont mesurés au moyen de premiers transducteurs (54) associés au premier microprocesseur et au moyen de seconds transducteurs (54) associés au second microprocesseur, les microprocesseurs étant agencés de façon à comparer d'une manière indépendante les valeurs de paramètre mesurées aux constantes de réglage rangées dans le registre de mémoire associé.

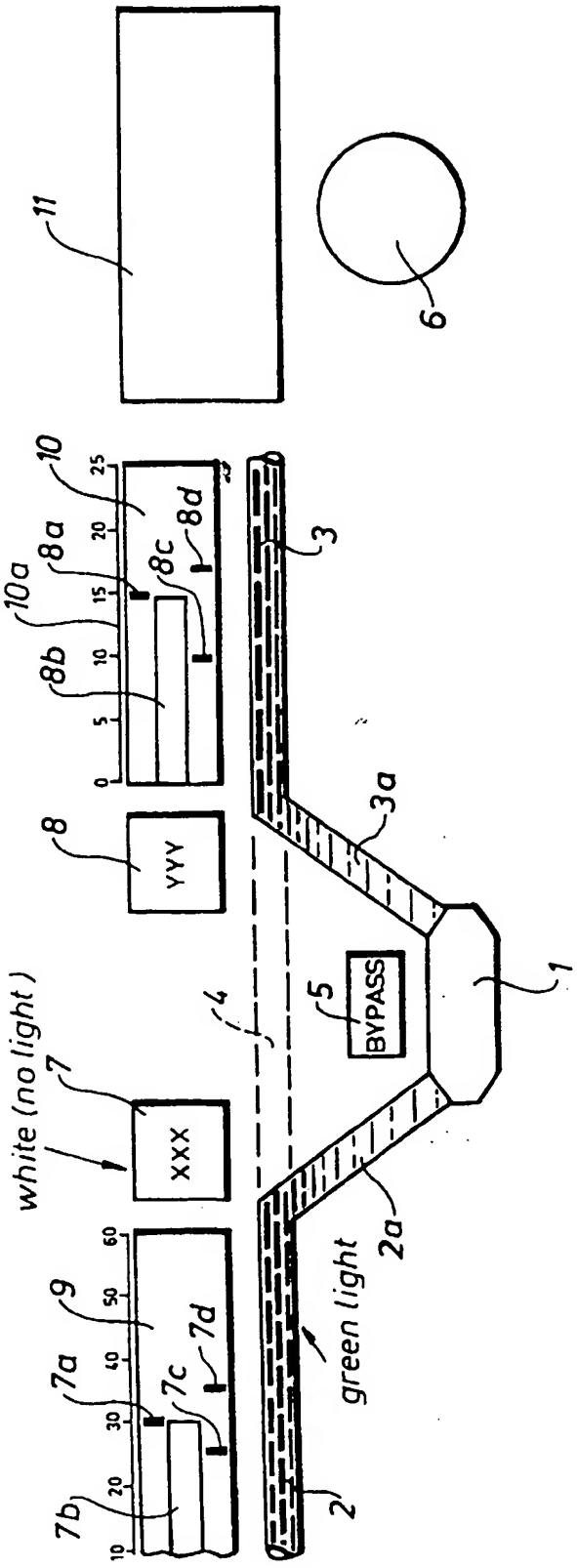
8. Appareil de réglage selon la revendication 6 ou 7, dans lequel des éléments ajustables (62) influent sur lesdits paramètres, caractérisé en ce que le premier microprocesseur est agencé de façon à comparer un échantillon d'un paramètre donné, prélevé au moyen du premier transducteur associé, aux constantes de réglage rangées dans ledit registre de mémoire, de façon à fournir auxdits moyens d'actionnement un signal de réglage servant à ajuster le paramètre de façon qu'il prenne une valeur donnée par les constantes de réglage et/ou de façon qu'il soit situé entre certaines valeurs limites données par les constantes de réglage, et en ce que le second microprocesseur est agencé de façon à comparer un échantillon, prélevé au moyen du second détecteur associé, aux constantes de réglage rangées dans le second registre de mémoire, de façon à fournir un signal d'alarme (5) lorsque ledit échantillon est situé en dehors des valeurs limites données par les constantes de réglage.

9. Appareil de réglage selon l'une quelconque des revendications 5 à 8, caractérisé en ce que les moyens de duplication numérique (48) font partie de l'un (44) des microprocesseurs (44, 50).

10. Appareil de réglage selon l'une quelconque des revendications 5 à 9, caractérisé en ce que ledit paramètre est sélectionné dans le groupe constitué par les conductibilité, température, débit de fluide, pression transmembranaire, volume de produit d'ultrafiltration, vitesse d'ultrafiltration, temps, composition chimique, pH et pertes de sang.

Fig. 1

Normal


11
6
10
25
20
15
10
5
0
10a
8a
8c
8d
8b
3
8
YYY
3a
1
5
BYPASS
4
white (no light)
7
XXX
2a
green light
60
50
40
30
20
10
9
7a
7c
7d
7b
2

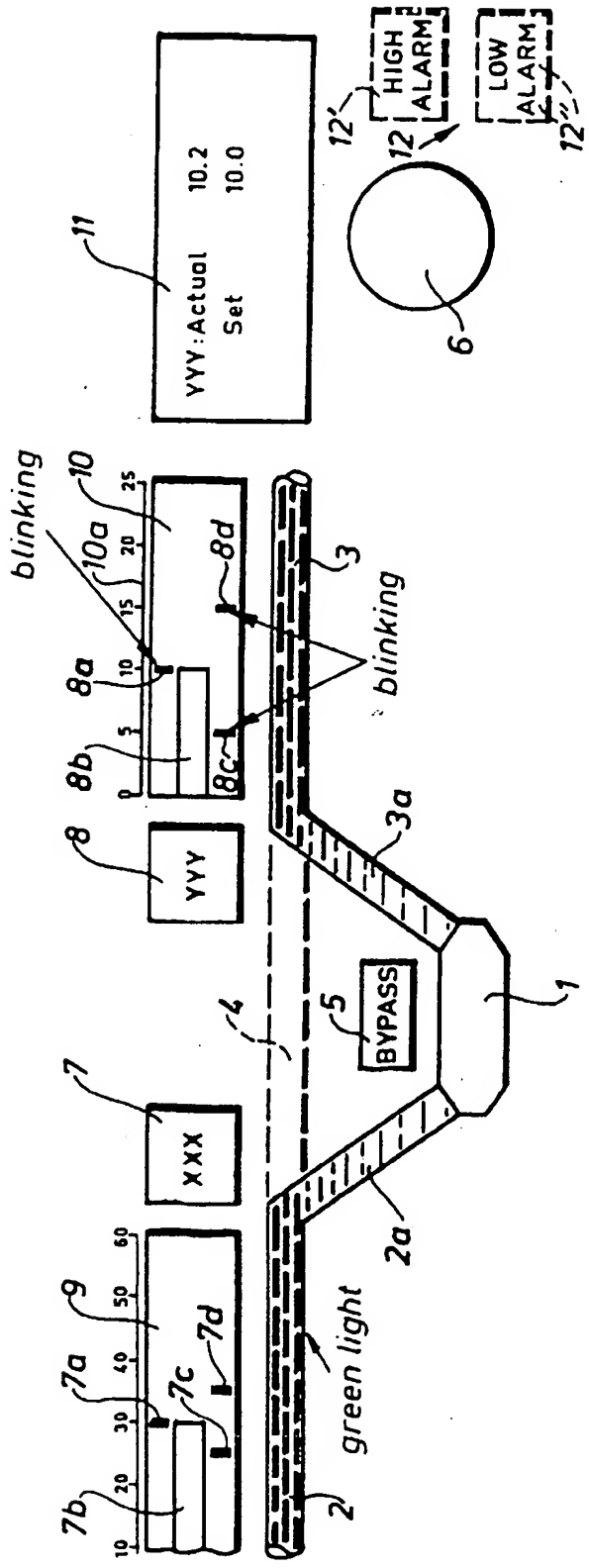


Fig. 2

Changed YYY-no alarm

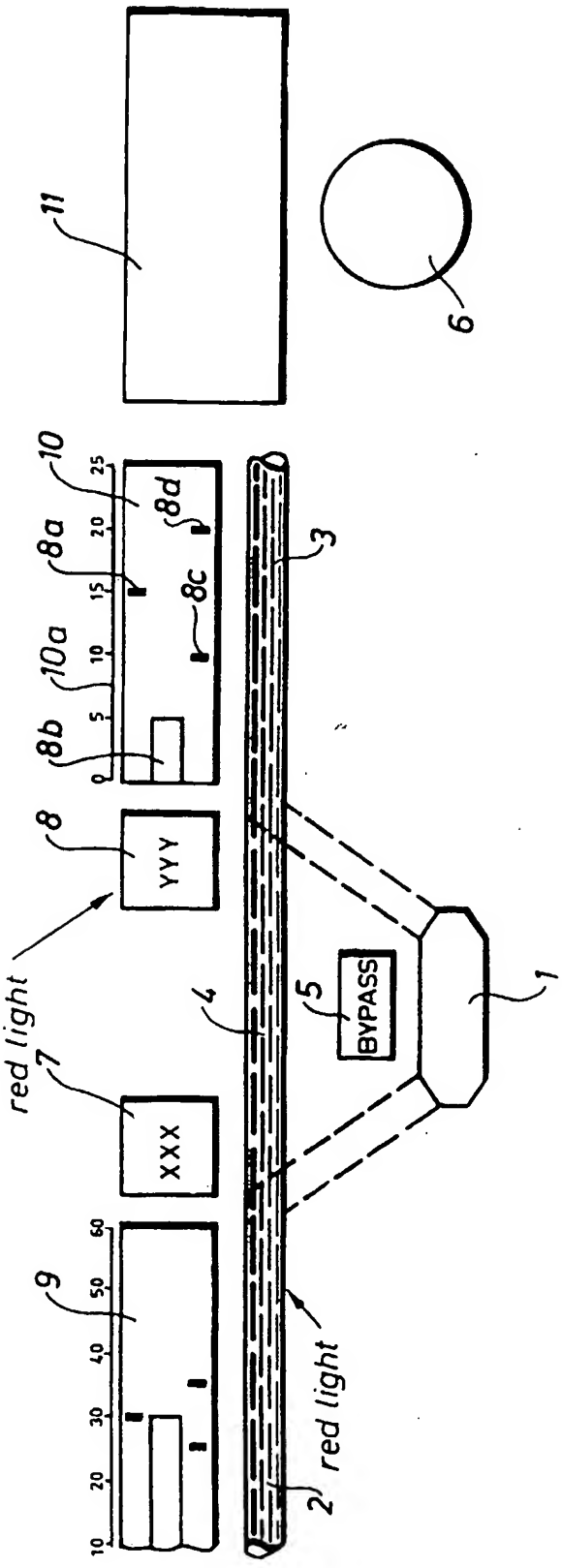


Fig. 3

Alarm—bypass

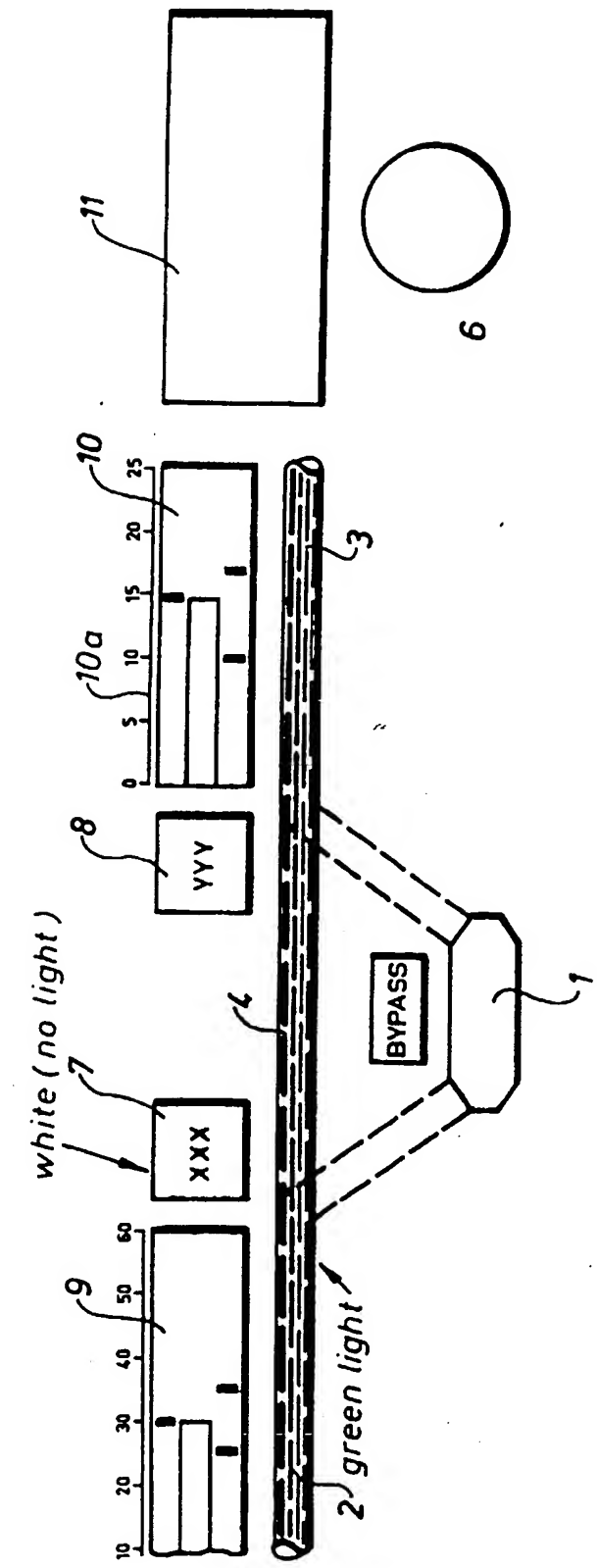


Fig. 4

No alarm — bypass

Fig. 5

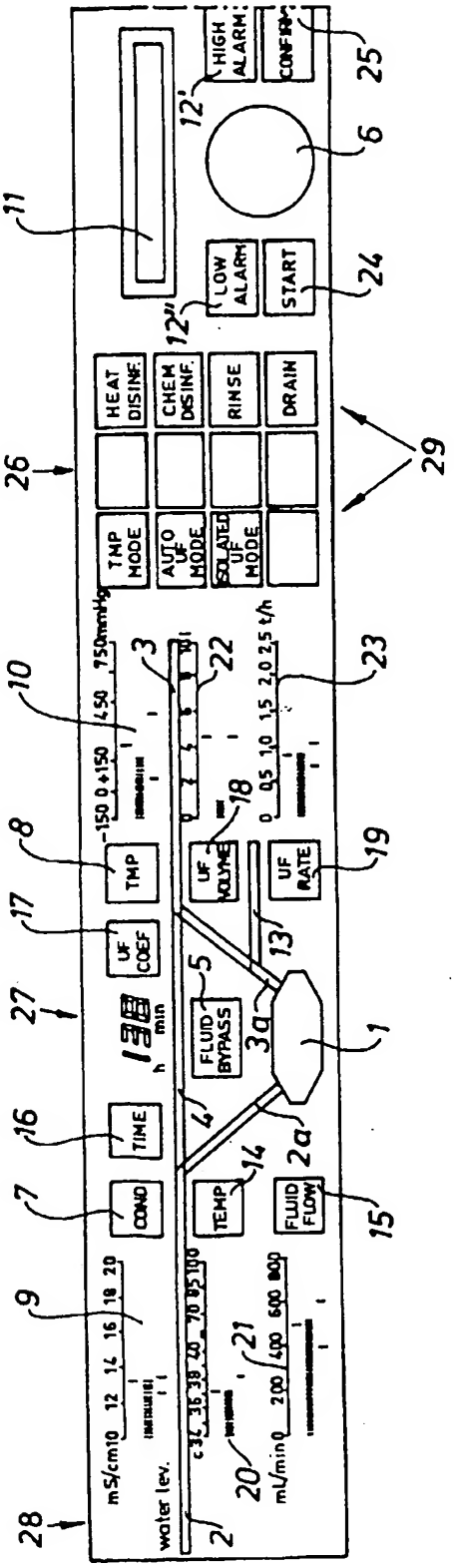
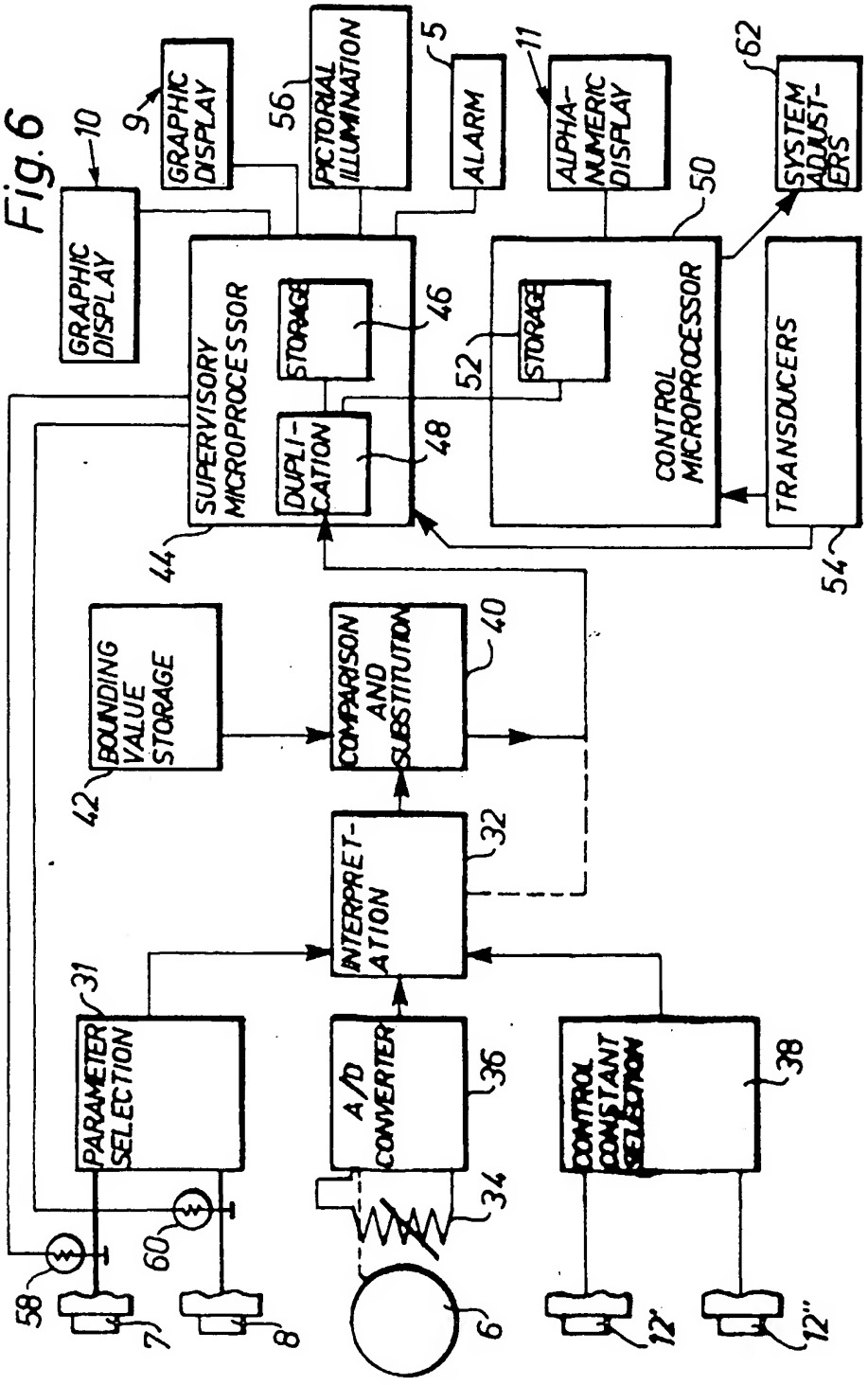

HIGH ALARM
CONFIRM
LOW ALARM
START
HEAT DISINF.
CHEM DISINF.
RINSE
DRAIN
TMP MODE
AUTO UF MODE
ISOLATED UF MODE
TMP
UF COEF
TIME
COND
TEMP
FLUID FLOW
UF VOLUME
UF RATE
FLUID BYPASS
mS/cm
water lev.
mL/min
t/h
1
2
2a
3
3a
4
5
6
7
8
9
10
11
12'
12"
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29

Fig.6


GRAPHIC DISPLAY
10
GRAPHIC DISPLAY
9
PICTORIAL ILLUMINATION
56
ALARM
5
ALPHA-NUMERIC DISPLAY
11
SYSTEM ADJUST-ERS
62
SUPERVISORY MICROPROCESSOR
STORAGE
46
DUPLI-CATION
48
44
CONTROL MICROPROCESSOR
50
STORAGE
52
TRANSDUCERS
54
BOUNDING VALUE STORAGE
42
COMPARISON AND SUBSTITUTION
40
INTERPRET-ATION
32
PARAMETER SELECTION
31
A/D CONVERTER
36
CONTROL CONSTANT SELECTION
38
58
60
7
8
34
6
12'
12''